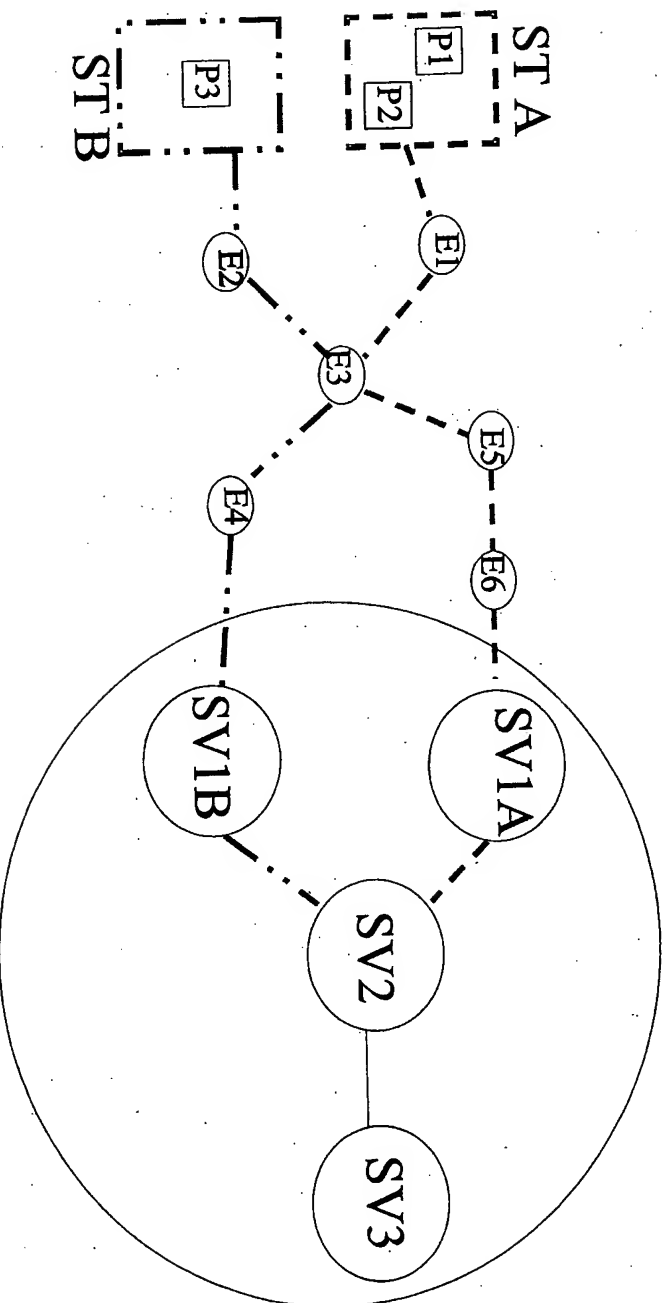


FIG 1: Probing Technology

Probes = test transactions (e.g., ping, traceroute, mail- or web-access)



ST – Probe station
P – Probe
E – Element
SV - Service

FIG 1: Probing Technology

Example

N_1 N_2 N_3 N_4 N_5 N_6
 P_{15} 1 1 0 0 1 0

P_{15} FAIL \Rightarrow Problem with
 $\{N_1, N_2, N_5\}$

P_{15} OK \Rightarrow Problem with
 $\{N_3, N_4, N_6\}$ or No Problem

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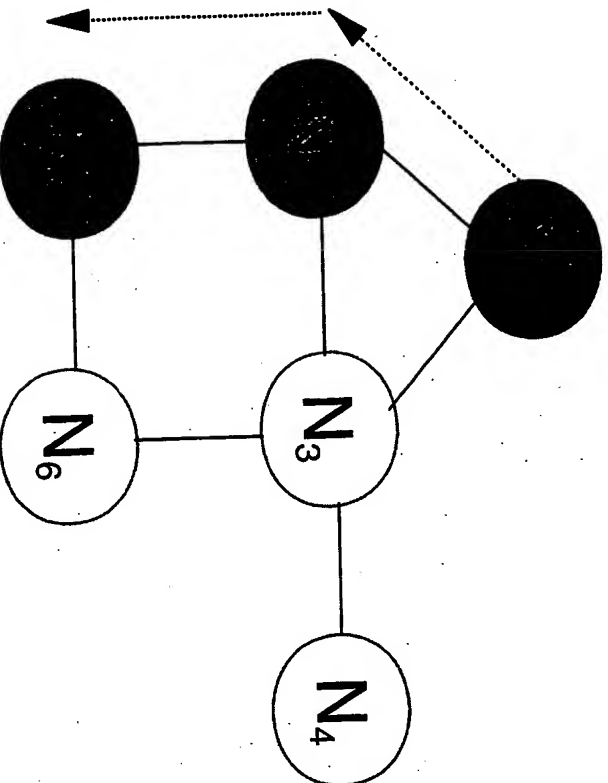


FIG 2: A single probe

Example

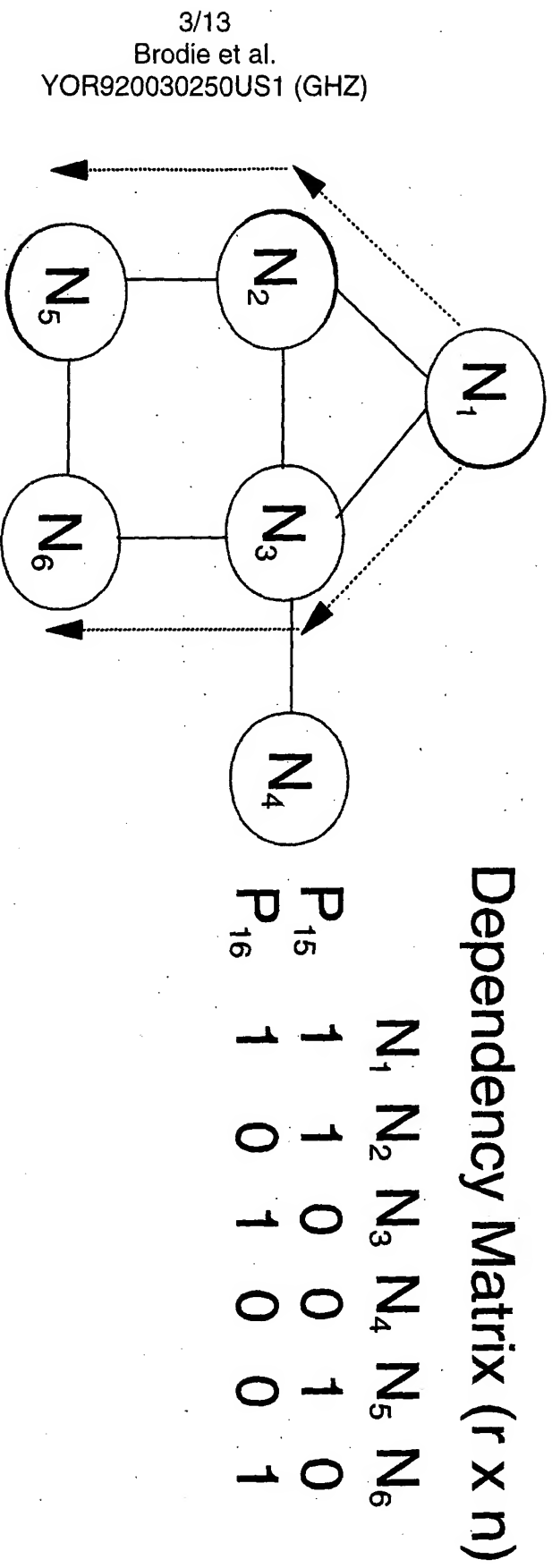
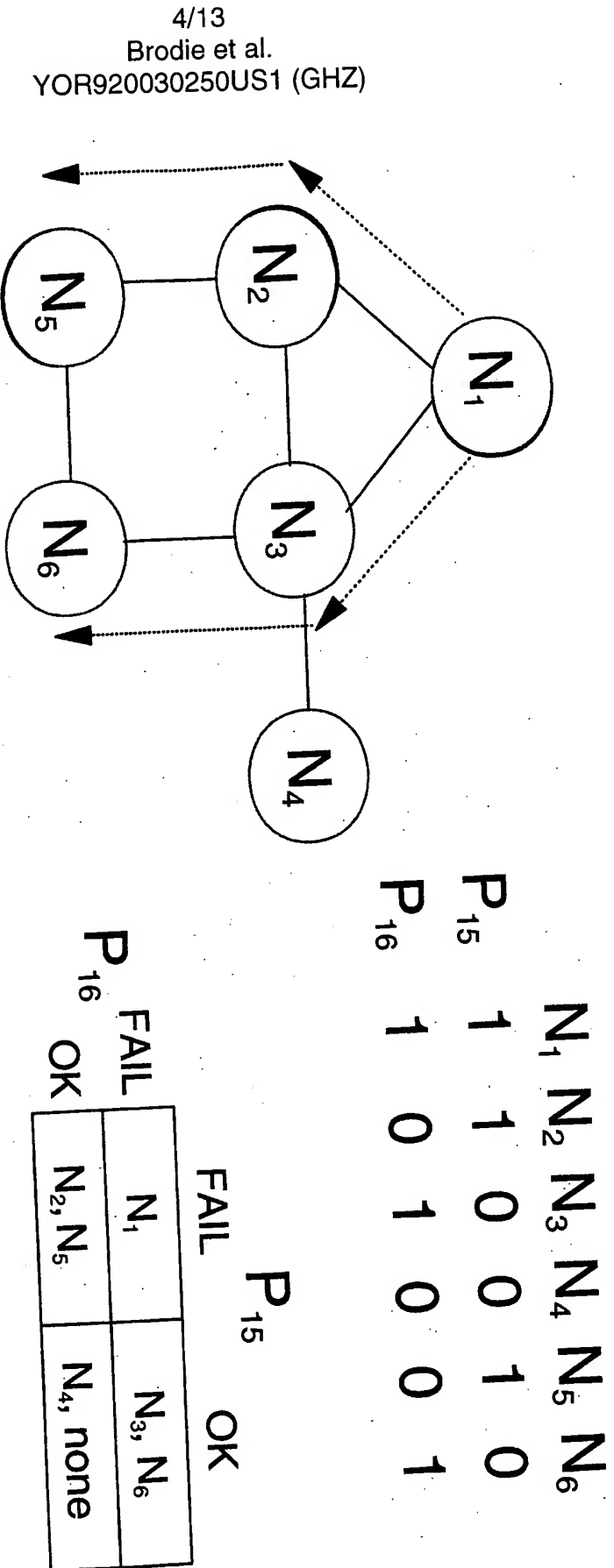


FIG 3: Two probes - a dependency matrix
 r = number of probes, n =number of nodes

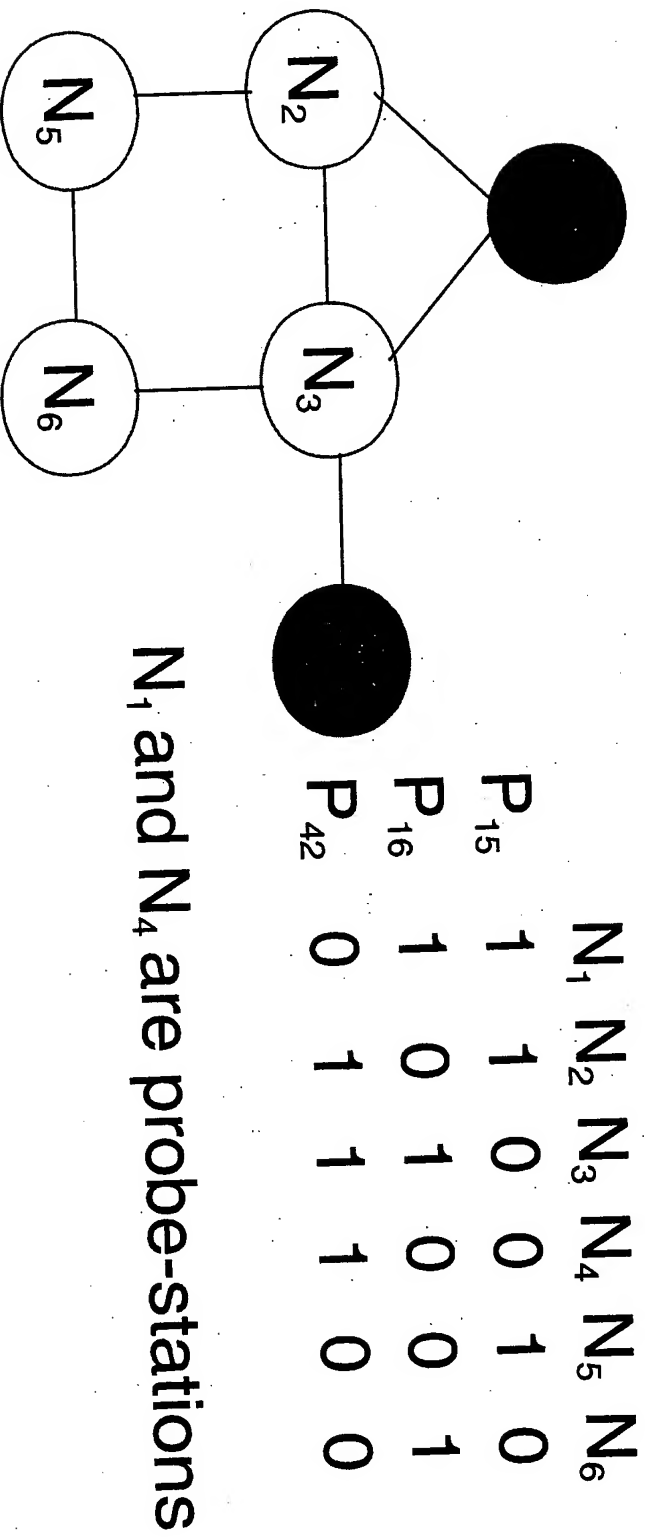
Example



"Diagnosable Problems" are $\{ \{N_1\}, \{N_2, N_5\}, \{N_3, N_6\}, \{N_4, \text{none}\} \}$

FIG 4: Probe Signals and Diagnosable Problems

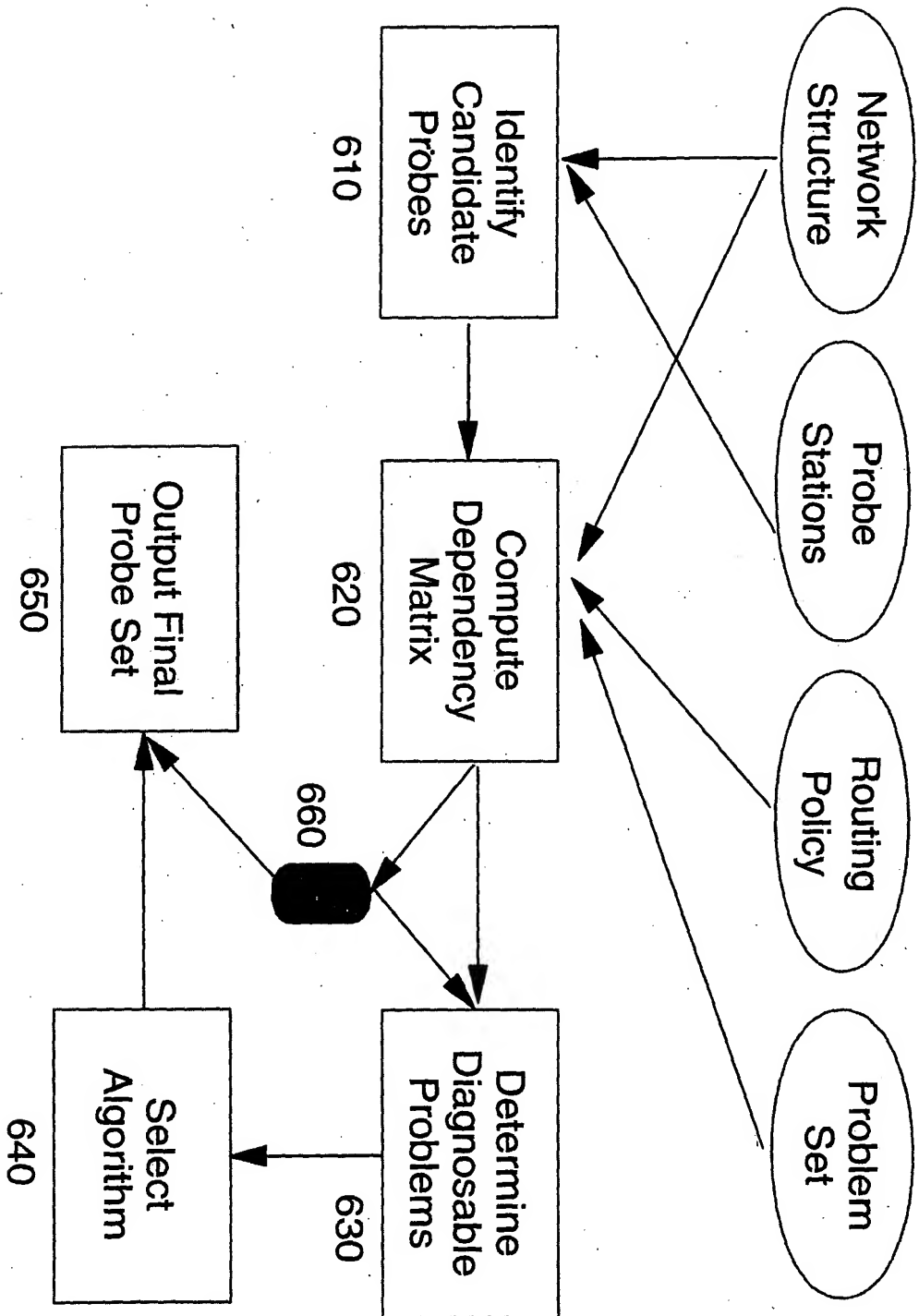
Diagnosing Any Failure



Diagnosable Problems are $\{ \{N_1\}, \{N_2\}, \{N_3\}, \{N_4\}, \{N_5\}, \{N_6\}, \{\text{"none"}\} \}$

FIG 5: All problems diagnosed by 3 probes

FIG 6: System Architecture



Compute Dependency Matrix

Find every allowable path from each probe station to each node.

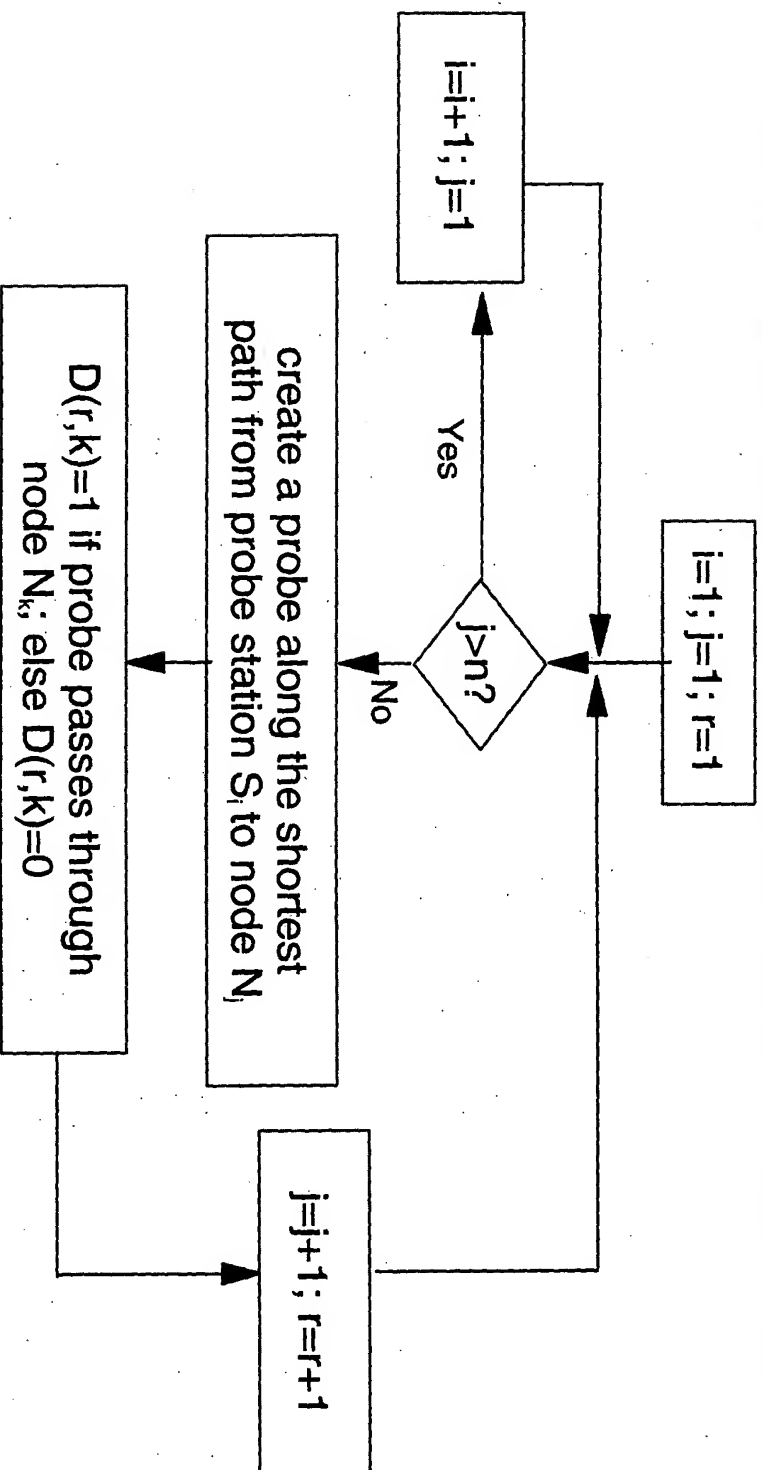
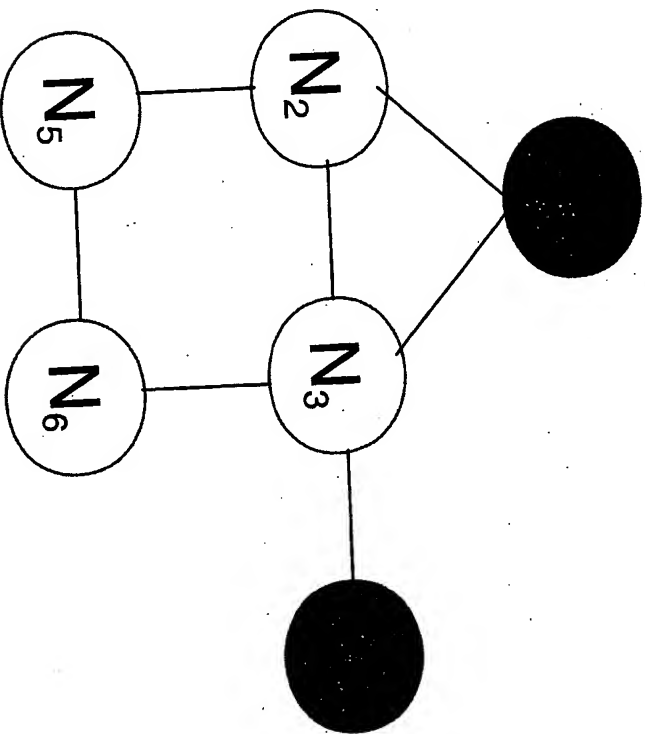


Fig 7: Computing the initial dependency matrix

Initial Dependency Matrix



Dependency Matrix (r by n)

	N ₁	N ₂	N ₃	N ₄	N ₅	N ₆	NF
P ₁₂	1	1	0	0	0	0	0
P ₁₃	1	0	1	0	0	0	0
P ₁₄	1	0	1	1	0	0	0
P ₁₅	1	1	0	0	1	0	0
P ₁₆	1	0	1	0	0	1	0
P ₄₂	0	1	1	1	0	0	0
P ₄₃	0	0	1	1	0	0	0
P ₄₅	0	1	1	1	1	0	0
P ₄₆	0	0	1	1	0	1	0

FIG 8: An example of the initial dependency matrix
 N₁ and N₄ are probe-stations - there is one probe from each
 probe-station to each node, following shortest path routing.

Determine Diagnosable Problems

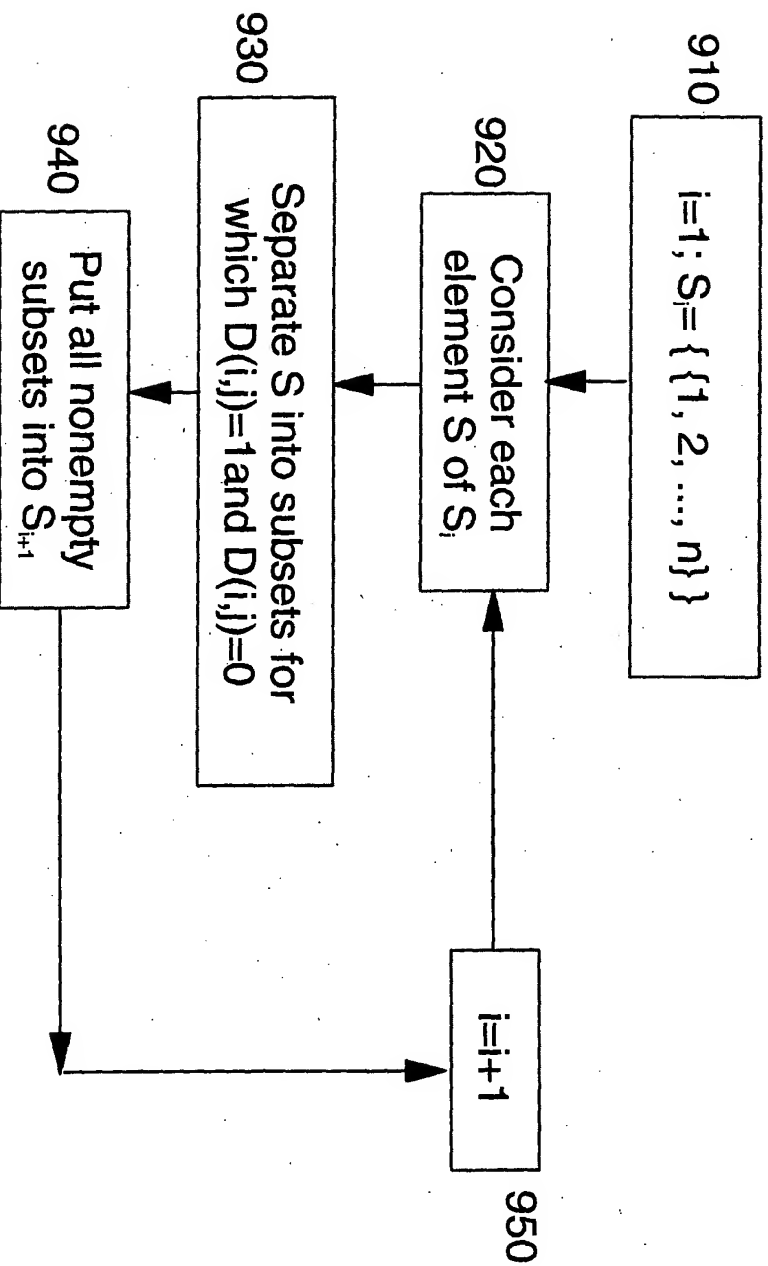


FIG 9: Computing the diagnosable problems of a probe set.

Example

$$(0) \quad S_0 = \{ \{N_1, N_2, N_3, N_4, N_5, N_6, NF\} \}$$

$$(1) \quad N_1 \ N_2 \ N_3 \ N_4 \ N_5 \ N_6 \ NF$$

$$P_{15} \quad 1 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0$$

$$S_1 = \{ \{N_1, N_2, N_5\}, \{N_3, N_4, N_6, NF\} \}$$

$$(2) \quad N_1 \ N_2 \ N_3 \ N_4 \ N_5 \ N_6 \ NF$$

$$P_{16} \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0$$

$$S_2 = \{ \{N_1\}, \{N_2, N_5\}, \{N_3, N_6\}, \{N_4, NF\} \}$$

$$(3) \quad N_1 \ N_2 \ N_3 \ N_4 \ N_5 \ N_6 \ NF$$

$$P_{42} \quad 0 \quad 1 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0$$

$$S_3 = \{ \{N_1\}, \{N_2\}, \{N_3\}, \{N_4\}, \{N_5\}, \{N_6\}, \{NF\} \}$$

FIG 10: An example of computing the diagnosable problems of a given probe set

Exhaustive Search

ProbesThru(i) = all probes passing through N_j .

$A \times B$ = all sets containing one element from A and a distinct element from B .

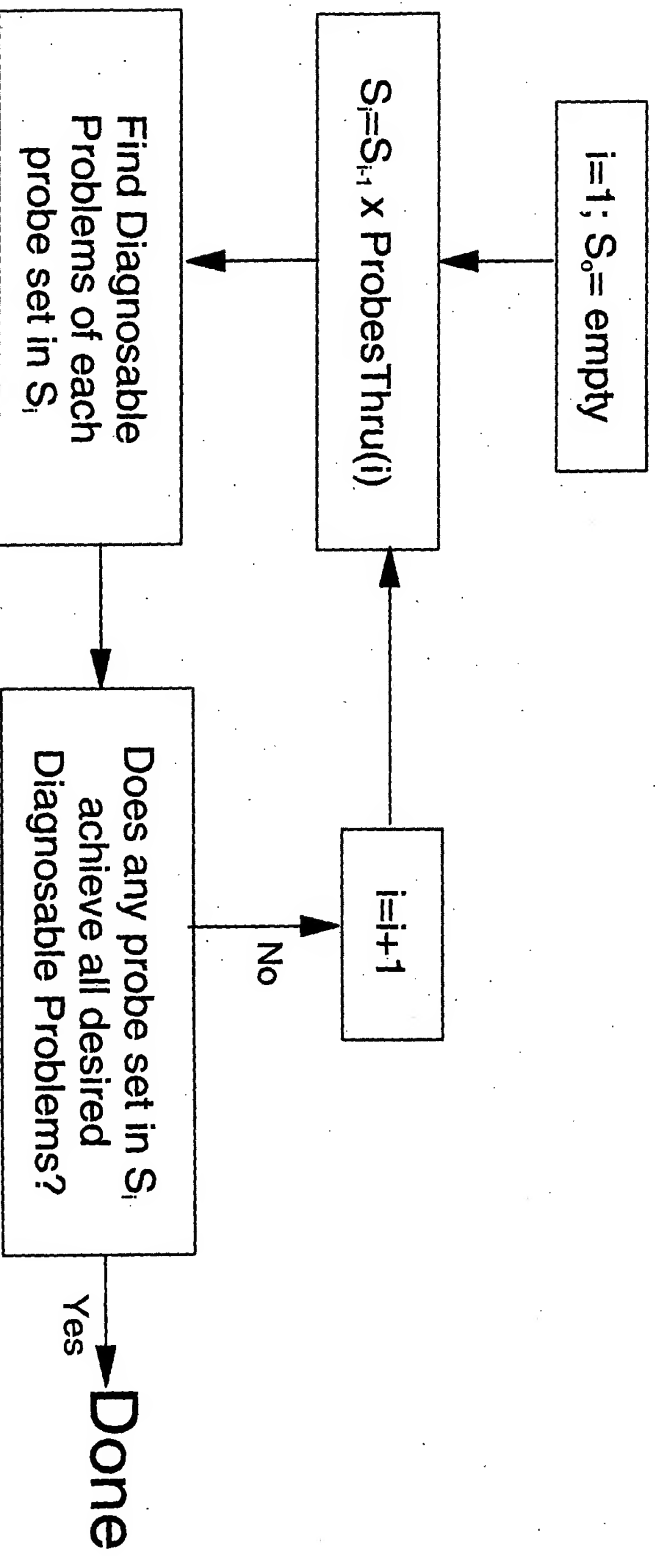


FIG 11: Exhaustive Search to find the minimal probe set

Quick Search

Idea: Throw away probes that are not needed.

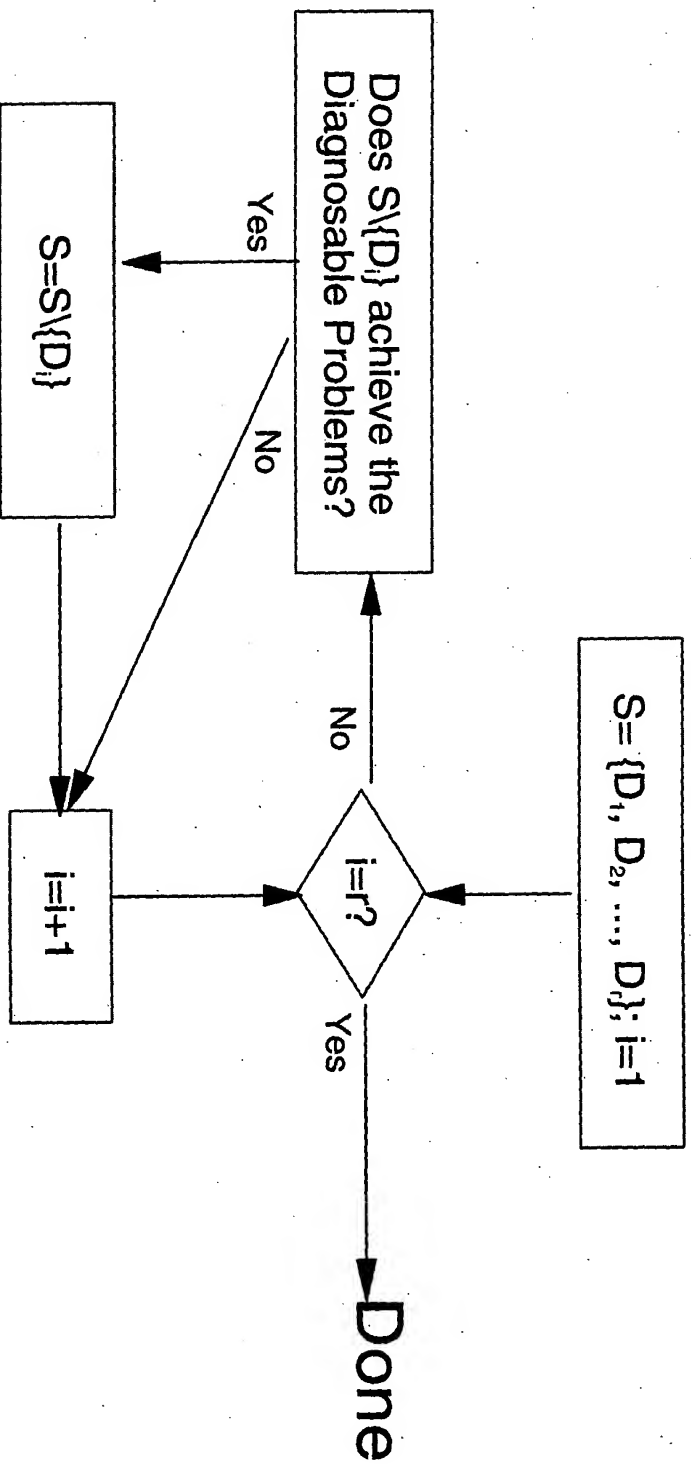


FIG 12: Quick Search to find a small probe set

Greedy Search

Idea: Add the "best" probe at each step.

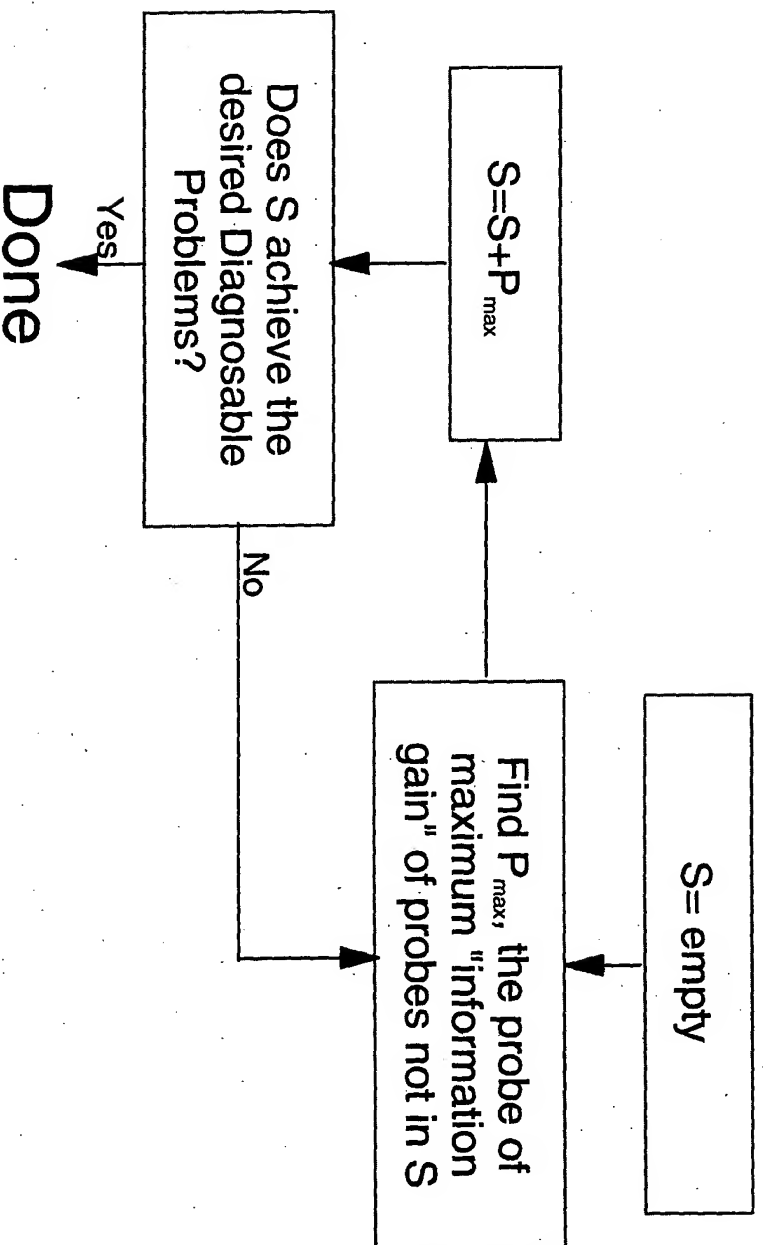


FIG 13: Greedy Search to find a small probe set